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Macrocurrent and Microcurrent Electrostimulation in Sport

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(*Note:* This article drew extensively on material from the textbook, Siff MC & Verkhoshansky YV *Supertraining* 1999. Anyone requiring further information on this topic should consult Chapter 4 of this book.)

The use of electric current on the human body largely has been restricted to use by physiotherapists to facilitate the healing of musculoskeletal injuries and control pain. It is fairly arbitrarily applied in two broad categories:

- Macrocurrent Stimulation (currents over about 1 milliamp)
- Microcurrent Stimulation (currents below about 1 milliamp)

The former usually refers to Faradic, Interferential, Galvanic and TENS (Transcutaneous Electrical Nerve Stimulation) devices, whereas the latter refers to specialised microcurrent devices for application either to the musculoskeletal system or as a non-invasive form of electroacupuncture via the acupuncture points of the body or the auricular points of the ears. The differences between these applications will be discussed later in this article.

The concept of electrostimulation for physical conditioning is not new, and for years has been used by physical therapists in clinical applications such as muscle rehabilitation, relief of muscular spasm, reduction of swelling and pain control. Its possible value in sports training is still considered controversial. In strength conditioning, the potential applications of electrostimulation fall into the following broad categories:

- Imposition of local physical stress to stimulate supercompensation
- Local restoration after exercise or injury
- General central nervous and endocrine restoration after exercise or injury
- Neuromuscular stimulation for pain control or movement patterning

Electrostimulation usually involves feeding the muscles low current electrical impulses via moistened electrode pads placed firmly on the skin. The effectiveness, comfort and depth of excitation depends on factors such as pulse shape, frequency, duration, intensity and modulation pattern. The resulting number of possible stimulation combinations immediately emphasizes how difficult it is to determine the optimum balance of variables and compare the results of different researchers.

The typical clinical machine supplies pulsating direct (galvanic) and/or alternating (faradic) current in the form of brief pulses. The frequency of faradic current is most commonly chosen in the range of about 50-100 Hz, while pulse duration (width) ranges from about 100 microseconds to several hundred milliseconds. This brevity of pulse duration is important for minimising skin irritation and tissue damage. However, the duration at any particular intensity of faradic stimulation should not be too brief. Although they may be suitable for decreasing pain, pulses that are too brief will supply insufficient energy to cause full, tetanic muscle contraction.

Machines are designed to apply alternating currents directly at a preset or selected frequency (conventional faradism), or in the form of low frequency currents superimposed on a medium frequency (2000 to 5000 Hz) carrier wave. A variation of the latter method, using two pairs of electrodes each supplying medium frequency waves carrying low frequency waves differing slightly in frequency, forms the basis of what is called interferential stimulation. A major advantage of using a higher frequency carrier wave is that impedance between the electrodes and skin is lowered, enhancing comfort and effectiveness.

American interest in electrostimulation as a training adjunct was aroused in 1971, when Kots in Russia reported increases of more than 20% in muscle strength, speed and power produced by several weeks of electrotraining. Unable to produce comparable results, the Canadians invited him to lecture at Concordia University in 1977. Armed with the new information that Kots employed a sinusoidally modulated 2500 Hz current source applied in a sequence of 10 seconds of contraction followed by 50 seconds of relaxation, they again tried to duplicate Russian claims.

Applications of Macrocurrent Stimulation

A literature review reveals the following major uses of macrocurrent stimulation in the realm of therapy. A more detailed discussion or the citations are not quoted here, but appear in my review on this topic [Siff M C (1990) Applications of electrostimulation in physical conditioning: a review *J of Appl Sports Science Res* 4 (1) : 20-26], as well as in the textbook: Siff MC & Verkhoshansky YV (1999) *Supertraining*, Ch 4.

1. Increase in muscle strength
2. Re-education of muscle action
3. Facilitation of muscle contraction in dysfunctional or unused muscle
4. Increase of muscular and general endurance
5. Increase in speed of muscle contraction
6. Increase in local blood supply
7. Provision of massage
8. Relief of pain
9. Reduction of muscle spasm
10. Promotion of relaxation and recuperation
11. Increase in range of movement
12. Reduction of swelling
13. Reduction of musculoskeletal abnormalities
14. Preferential recruitment of specific muscle groups
15. Acute increase in strength
16. Improvement in metabolic efficiency

The Emergence of Microcurrent Stimulation

Recent research and clinical experience have revealed that electric currents as much as 1000 times smaller than that of all the traditional physical therapy modalities can be far more successful than the latter in achieving many of the benefits outlined in the previous section.

Currents as low as 10 microamps (millionths of an amp) pulsating at between 0.1 to 400Hz are too weak to cause muscle contraction, block pain signals or cause local heating, yet their effectiveness and safety is often superior in many applications to that of faradism, interferentialism and conventional TENS (Matteson & Eberhardt, 1985).

The steps to satisfactorily modify the existing paradigm for ES may be sought in the research findings quoted earlier in the section: 'Reasons for conflicting research'. There, it was learned that cellular and subcellular processes not involving cell discharge, propagated electrical impulses, or muscle contraction, appear to be involved with cellular growth and repair.

Some studies have produced findings which offer partial answers to the questions posed by microstimulation. For instance, work by Becker and others suggests that small, steady or slowly varying currents can cause sub-threshold modulation of the electric fields across nerve and glial cells, thereby directly regulating cell growth and communication (Becker, 1974; Becker & Marino, 1982). In this respect, some of Becker's applications included the acceleration of wound healing, partial regeneration of amphibian and rat limbs, and induction of narcosis with transcranial currents. Nordenström maintains that these electric currents can stimulate the flow of ions along the blood vessels and through the cell membranes which constitute the body's closed electric circuits postulated by his theory (Nordenström, 1983).

Pilla (1974) has paid particular attention to electrochemical information transfer across cell membranes. The model in this case hypothesizes that the molecular structure of the cell membrane reflects its current genetic activity. Here, the function of a cell at any instant is determined by feedback between DNA in the cell nucleus and a macromolecule inducer liberated from the membrane by means of a protein (enzyme) regulator derived from messenger RNA activity within the cell. The activity of these membrane-bound proteins is strongly modulated by changes in the concentration of divalent ions (such as calcium Ca^{++}) absorbed on the membrane. ES may elicit these ionic changes and thereby modify cell function.

It has been shown that ES at 5Hz stimulates synthesis of DNA in chick cartilage cells and rat bone by as much as 27%, but not in chick skin fibroblasts or rat spleen lymphocytes (Rodan et al, 1978). Not only does the effect of ES appear to be tissue-specific, but the increase in DNA synthesis occurs 4-6 hours after 15 minutes of ES. The process of membrane depolarisation carried by sodium ions seems to be followed by an increase in intracellular Ca^{++} concentration, thereby triggering DNA synthesis in cells susceptible to the particular stimulus. Further work by Pilla (1981) has confirmed the existence of cellular 'windows' which open most effectively to certain frequencies, pulse widths and pulse amplitudes. To attune the ES signal to these parameters, monitoring of tissue impedances is preferable, a system employed by so-called 'Intelligent TENS' devices (e.g., Electro-Acuscope).

In addition, Cheng et al (1982) have shown that stimulation with currents from 50-1000 microamps can increase tissue ATP concentrations in rats by 300-500%, and enhances amino acid transport through the cell membrane and consequent protein synthesis by as much as 40%. Interestingly, the same study reported that increasing the current above only one milliamp was sufficient to depress tissue ATP and protein synthesis - and traditional ES most commonly applies currents exceeding 20 milliamps, at which stage this depression being nearly 50%.

An Integrated Theory of Electrostimulation

Therefore, it appears as if macrocurrent stimulation (MACS - currents exceeding one milliamp) acts as a physiological stressor, which in the short term causes the typical alarm response described by Selye (1975). This is supported by the work of Eriksson et al (1981), who found that the acute effects of traditional ES are similar to those found for intense voluntary exercise. Furthermore, Gambke et al (1985) have found in animal studies that long-term MACS causes some muscle fibres to degenerate and be replaced by newly formed fibres from satellite cell proliferation. This fibre necrosis occurs a few days after application of ES and seems to affect mainly the FT fibres. The fact that the various muscle fibres do not transform at the same time may be due to different thresholds of each fibre to the stimulus that elicits the transformation. Possibly, the earlier changes might induce subsequent ones.

Thus, if Selye's General Adaptation Syndrome model is applied to MACS-type stimulation, the body would have to draw on its superficial adaptation energy stores and adapt to the ES-imposed stress by increasing strength or endurance, or by initiating transformation of muscle fibre types. If the ES is too intense, too prolonged or inappropriately used to augment a weight training programme, adaptation might not occur or it might increase the proportion of slow twitch fibres and thereby reduce strength. This could explain some of the negative research findings discussed earlier.

Furthermore, excessively demanding MACS conceivably might cause the body to draw on its deep adaptation energy and lead to permanent tissue damage. Consequently, any athlete who may derive definite performance benefits from MACS should not assume that increased dosage will lead to further improvement. The contrary may well prove to be true.

Microcurrent stimulation (MICS - currents below one milliamp), on the other hand, would not act as a stressor. Instead, the evidence implies that it elicits biochemical changes associated with enhanced adaptation, growth and repair. Since MICS appears to operate more on the basis of resonant attunement of the stimulus to cellular and subcellular processes, the specific therapeutic effects are determined by how efficiently the stimulation parameters match the electrical characteristic of the different cells, in particular, their impedance at different frequencies. MICS may be applied in several ways to facilitate restoration:

- locally over specific soft tissues
- transcranially via electrodes on the earlobes or on sites on the surface of the skull
- at acupuncture points on the body, hands or ears.

It is generally entirely safe to apply MICS anywhere on the body, because the current and energy transmitted is too low to produce any thermal or electrolytic effects on vital tissues. Under no circumstances should MACS be applied across the brain, as it can cause serious harm. It is generally not advisable to apply any form of ES to epileptics, pregnant women, cardiac patients or persons with heart pacemakers.

The Validity of Microcurrent Application?

There has been considerable debate about the value of microcurrent (small electrical currents of less than 1 ampere) in physical therapy, with its supporters claiming consistently good results and its detractors claiming that any benefits are probably due to a placebo effect. Some therapists have stated that there is scant evidence of any research and practical evidence of the value of microcurrent, so, for their interest and that of others conducting research into microcurrent therapy, I have compiled a lengthy, but incomplete, list of English language references that relate to the theoretical foundations and clinical applications of microcurrent.

My own interest in this field was piqued while I was gathering research information for my M.Sc into the mechanisms underlying the electroencephalogram (EEG) in brain research. While browsing in the old science library I located in the physics building at the University of the Witwatersrand, South Africa during 1971, I encountered a few fascinating texts: one edited by Barnothy (1969) and another by Presman (1970), as well as several articles by Robert Becker, with whom I later had periodic contact over the years (these are all referenced below).

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July 2000